McGlamry's Comprehensive Textbook of Foot and Ankle Surgery

Third Edition

VOLUME TWO

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PART 2

Selected Arthrodesis

Gerard V. Yu and Jeffrey E. Shook

Arthrodesis of one or multiple joints has been an acceptable procedure for addressing joint disease for more than 100 years. The term *arthrodesis* (*arthro,* joint, and *desis,* to bind) was coined by Albert in a description of a procedure he performed to stabilize a "paralyzed knee" on July 10, 1873. Albert was erroneously credited for performing this first procedure because Bauer and Szymanowski performed a similar type of fusion before Albert's description (1).

Between 1880 and 1940, numerous arthrodesing techniques were described (1–4). Reconstructive efforts focused on the treatment of neuromuscular disorders that affected the foot and ankle, most notably, poliomyelitis (5,6). Most of the procedures reviewed involved wedging and displacement techniques aimed at correcting severe joint deformities and malalignment. After osseous consolidation, realignment created a stable, functional lower extremity capable of ambulation without a brace. The most common procedure used to achieve this end point was triple arthrodesis or multilevel fusion (5–10).

Initially, the "workhorse" procedure for severe foot deformity was the *Whitman talectomy,* with emphasis on the posterior displacement of the foot on the leg after extirpation of the talus (11). The subsequent development of alternative arthrodesing procedures resulted from dissatisfaction with talectomy, which resulted in significant architectural alteration of the foot and limited stability. The main objection to talectomy was the significant weakening of the foot after the procedure, especially when it was used for the treatment of equinovarus and cavovarus deformities associated with paralytic conditions (1–4).

Soule recognized that deformity was not associated with the talus in cases of infantile paralysis and directed efforts toward correction of deformity of the talonavicular and calcaneocuboid joints (12). Likewise, Davis addressed the subastragaloid joints with a wedge resection of the subtalar joint and posterior displacement of the foot on the leg by appropriate resection of the talonavicular joint (13). The trend of osseous wedge resection at the subtalar and midtarsal joints followed by posterior displacement of the foot continued. In 1921, Hoke described removal and reshaping of the talar head and neck followed by reimplantation for fusion of the subtalar and talonavicular joints (14). Naughton Dunn achieved similar posterior displacement of the foot through medial column shortening by completely removing the navicular and performing subtalar, calcaneocuboid, and talocuneiform fusions (15,16). Ryerson described the classic triple arthrodesis in 1923 and frequently added fusion of the naviculocuneiform, first metatarsal cuneiform, and fourth and fifth metatarsal base cuboid articulations when deemed necessary for complete structural correction (17). Other surgeons described similar procedures to provide lateral stabilization of the foot combined with posterior displacement (18–25) or ankle joint arthrodesis (26–29).

Over the past century, the cause of conditions that require triple arthrodesis has evolved from congenital neuromuscular disorders to acquired disorders that are primarily the result of trauma, congenital or developmental deformities, and abnormal biomechanics (30). Regardless of the cause of a disorder, many authors have favored triple arthrodesis for reconstructive rearfoot surgery (31–34), in some instances because of concerns that the patient may develop arthritis at adjacent joints if only one joint is fused (32–34). Specifically, the radiographic evidence of arthritic change at the talonavicular joint after isolated subtalar joint arthrodesis prompted support for triple arthrodesis. Radiographic evidence of degenerative joint disease at the talonavicular joint was reported in a significant number of patients after Grice extraarticular arthrodesis at 10-year follow-up (35). This phenomenon may result from altered kinematics about the midtarsal joint. Surface contact at the talonavicular joint was decreased by 46% after simulated subtalar joint arthrodesis in a cadaveric model (36).

Clearly, triple arthrodesis can provide satisfactory results for a multitude of foot deformities and is primarily indicated when the patient has significant instability, rigidity, articular deficit, or symptoms affecting both the subtalar joint and midtarsal joints (37–44). The procedure may also be indicated in other instances as well, particularly when an isolated fusion will not allow adequate realignment of the foot. However, triple arthrodesis significantly reduces pedal motion, and this change theoretically can place increased stress on the tibiotalar joint and lesser tarsal joints (45–51). In many instances, long-term follow-up studies have demonstrated radiographic evidence of osteoarthritic changes in adjacent joints after triple arthrodesis; however, like the changes seen in patients undergoing single joint fusions, one should carefully note that these radiographic changes rarely correlate with clinical symptoms and do not adversely affect the overall efficacy of the procedure (39,40,52–54). Furthermore, in early studies, the importance of restoring good alignment to

the foot was not appreciated. In many instances, surgeons were pleased simply to have achieved successful fusion. This failure to understand the importance of proper alignment after triple arthrodesis may account for many of the arthritic changes viewed in previous studies.

Isolated rearfoot fusions have been performed for the better part of the last century and can be used in some patients in lieu of triple arthrodesis to achieve adequate stability and correction of deformity with less surgical intervention and faster recovery while preserving some degree of rearfoot motion. Over the past decade, there has been renewed interest in the effectiveness of these procedures for disorders of the hindfoot complex when the condition is confined to and can be addressed at a single joint.

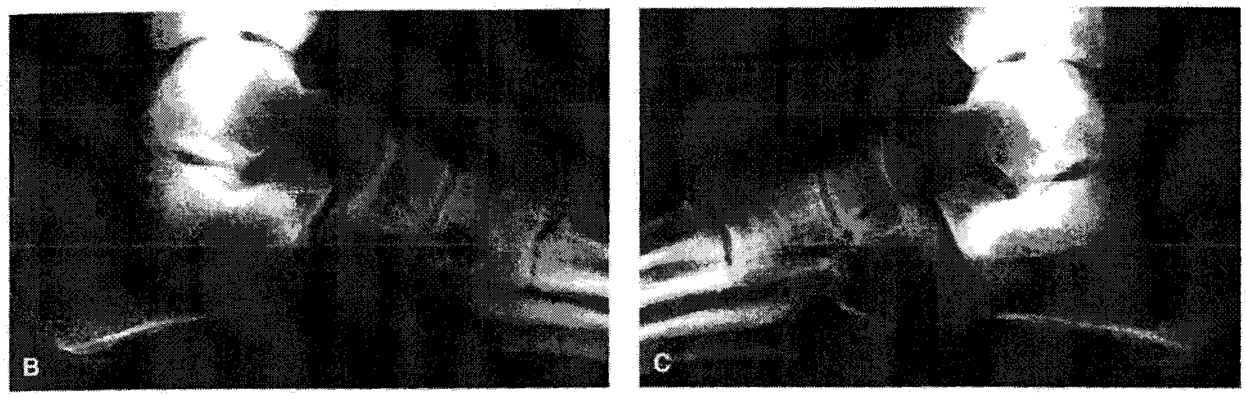
RATIONALE AND FUNCTIONAL CONSIDERATIONS

One of the potential disadvantages of any type of rearfoot fusion is the elimination or significant limitation of compensatory subtalar or midtarsal motion. This change can create increased stress at adjacent joints and may theoretically lead to degenerative joint disease in the adjacent joints. However, if the foot is placed in a good position and additional deforming influences are addressed or neutralized, then this potential complication can be minimized or altogether avoided. In part, this concept is a corollary, which has been deduced from significant experience in patients with isolated, asymptomatic tarsal coalitions. We have seen and have treated many patients who presented later in life with isolated tarsal coalitions, previously not identified clinically or radiographically. These occult conditions have remained silent for a lifetime, only to surface after a recent change in activity level or traumatic injury. In some cases, the coalition was merely an incidental finding of no consequence. Perhaps even more important is that signs of degenerative change in adjacent joints are rare in such patients.

Asymptomatic tarsal coalitions are most commonly seen in talonavicular coalitions, but we have observed a neutral or normal-appearing foot with minimal or no symptoms in patients with calcaneonavicular bars as well talocalcaneal coalitions. The reason for the lack of symptoms in this group of patients is that the foot is in a neutral position or the patient has experienced a developmental arthrodesis over time and has maintained relatively normal alignment of the foot (Fig. 33). In essence, this is the goal of an isolated rearfoot fusion—to create a foot that is stable with normal alignment.

Of interest has been the role of isolated joint fusion in the repair of deformity in patients with an adult acquired pes valgus deformity or tibialis posterior dysfunction (55–70). In many of these patients, severe malposition and instability, not intraarticular joint disease, is the indication for fusion. The architectural configuration of the individual tarsal bones

FIG. 33. An adult patient with an asymptomatic tarsal coalition. **A:** Dorsoplantar radiographs. Notice the excellent neutral alignment of the foot. *(continued)*



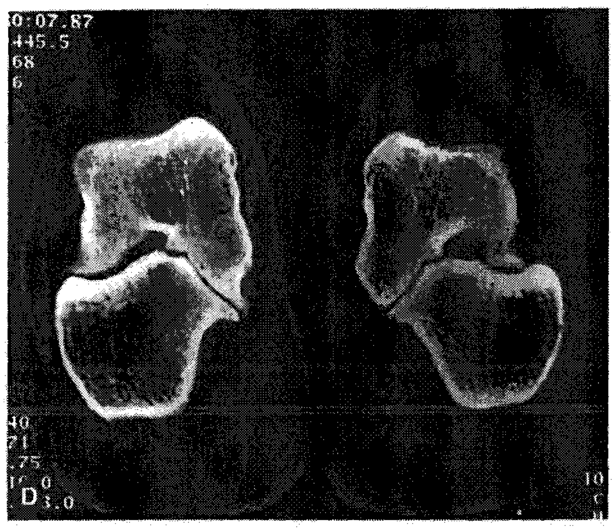


FIG. 33. *Continued.* **B,C:** Lateral radiographs of same patient demonstrating neutral alignment to the foot in the presence of subtalar joint tarsal coalition. **D:** Computed tomography scan confirming the presence of the tarsal coalition. **E:** Clinical photograph of the same patient. *(continued)*

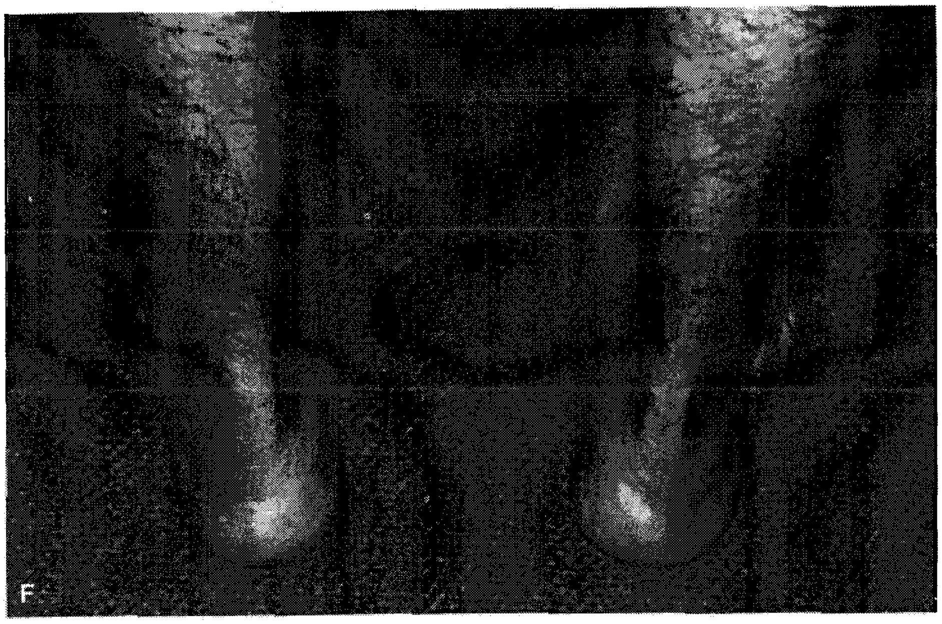


FIG. 33. *Continued.* **F:** Clinical photograph of the same patient.

(talus, calcaneus, navicular, and cuboid) is relatively normal; their relationship with adjacent bones is grossly abnormal. The significant malalignment can have a profound effect, not only on foot function, but also on the entire lower extremity segment because significant symptoms may be noted in the ankle, knee, hip, and lower back (71). If the goal is to restore a normal joint relationship, then fusion (single, double, or triple arthrodesis) is often the best approach and, with respect to realignment capabilities, is challenged only by subtalar joint arthroereisis in many cases.

PREOPERATIVE EVALUATION

The *clinical examination* is a critical step in evaluating patients who may undergo an isolated rearfoot fusion. To perform an isolated joint fusion in lieu of a triple arthrodesis for correction of deformity, one must be able to reposition the foot to the desired position of fusion with little resistance. When the joints can be repositioned but significant degenerative joint disease is present alone or in the presence of significant architectural changes of the tarsal bones, a double or, more commonly, triple arthrodesis is necessary (Fig. 34). In addition, in some patients who have more rigid deformity resulting from posttraumatic arthrosis, the decision between single and multiple joint fusions may be reserved until intraoperative evaluation and joint débridement have been performed.

Range of motion of the joints should be evaluated, and any pain or crepitation at a particular level correlated with the entire clinical picture. In most cases, flexible feet reduce to a ''normal'' or neutral position. If this can be achieved, a good prognosis is given for an isolated rearfoot fusion. The ankle should be evaluated for equinus deformity. In some patients, a mild degree of equinus may be overcome with subtalar fusion. Removal of the subtalar joint indirectly lengthens the superficial, posterior muscle group, and this may eliminate the need for any type of lengthening. The subtalar and midtarsal joints should be assessed for flexibility and reducibility of any deformity, and the forefoot-to-rearfoot relationship with the subtalar joint in a neutral position should be carefully evaluated. The difference in midtarsal joint motion with the heel inverted and maximally everted is a measure of the integrity of the subtalar-midtarsal joint locking mechanism. If a patient has no tendency to sublux at the midtarsal joint with the subtalar joint in a neutral position, then an isolated subtalar joint arthrodesis should be beneficial. However, if there is little difference in the amount of motion available at the midtarsal joint with the subtalar joint maximally pronated and held in neutral, then an isolated talonavicular or triple arthrodesis may be warranted.

In patients with a *rigid forefoot varus deformity,* the first ray remains elevated from the weight-bearing surface with the subtalar joint in a neutral position. If this sign is present, an ancillary procedure will be necessary to provide adequate alignment of the forefoot, or else a triple arthrodesis may be needed to provide the triplane correction required (Fig. 35).

The *maximal area of tenderness* should be localized and correlated with subjective complaint or symptoms. Differentiation between soft tissue and osseous pain should be attempted. When the maximal area of tenderness cannot be ascertained or when concern exists about multiple joint in-

FIG. 34. Dorsoplantar **(A)** and lateral **(B)** radiographs of patient with adult-acquired pes valgus deformity. Note the peritalar dislocation. **C,D:** Radiographs of the same patient in a neutral position demonstrating restoration of alignment to the subtalar-midtarsal joint complexes.

volvement, isolated joint infiltration with local anesthetic may prove beneficial in formulating treatment plan. Conservative treatment modalities may serve as diagnostic aids as well as therapeutic measures.

Sometimes patients may present with the same problem affecting *both extremities,* usually with less severe symptoms in the contralateral limb. Often, the disorder involves only one extremity. In the latter circumstance, examination of the contralateral limb may provide an understanding of what ''normal'' is with respect to structure and appearance.

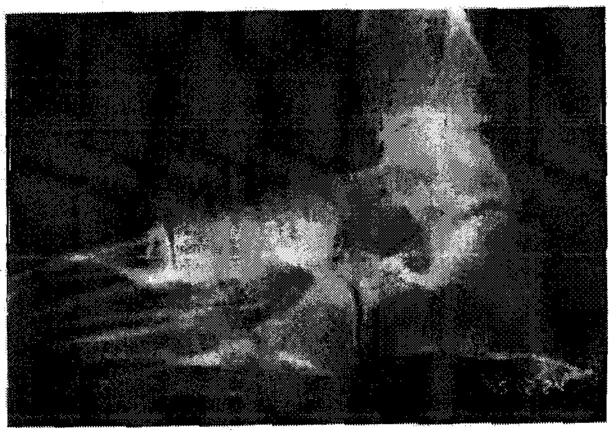


FIG. 35. Lateral radiograph of a patient in subtalar neutral position demonstrating medial column elevatus that may necessitate medial column fusion pending a correlation with the clinical findings.

In patients with bilateral disease, evaluation of the contralateral side may provide insight into individual patient needs relative to postoperative management.

Weight-bearing radiographs allow the surgeon to evaluate the functional alignment and relationships of the foot more carefully. In some instances, comparison with the contralateral extremity may also be of benefit in assessing the potential for relocation to a more functional alignment. If symptoms are caused by posttraumatic arthrosis, the adjacent joints should be evaluated for any degenerative change that could adversely influence the result of a single joint fusion. One may also consider ankle radiographs to evaluate ankle stability, especially if deltoid insufficiency is suspected (Fig. 36).

FIG. 36. Mild ankle valgus deformity of a patient with a subtalar joint coalition and pes valgus deformity. If not recognized, the valgus deformity of the ankle could potentially be problematic after successful arthrodesis of the subtalar joint. The same principle applies to other fusions of the foot, including isolated midtarsal fusion or triple arthrodesis.

SUBTALAR JOINT ARTHRODESIS

Historical Review

Isolated subtalar arthrodesis is an effective procedure for the treatment of many different disorders (61,63,64,68,69, 72–77). Subtalar arthrodesis was described by many authors for the treatment of paralytic pediatric deformities during the early 1900s. Historically, isolated subtalar arthrodesis has been predominately used to treat paralytic pediatric pes valgus deformity and the sequelae of intraarticular calcaneal fractures.

In the English literature, Wilson first gave the description of an isolated subtalar joint arthrodesis in 1927 to treat intraarticular disease secondary to a calcaneal fracture (78). At that time, there was limited enthusiasm for open reduction and internal fixation of these fractures, and poor results were encountered with casting or casting with traction. Many authors advocated arthrodesis as the primary treatment for calcaneal fractures as early as 1 week to 6 months after the initial injury (79–83). Gallie described a posterior approach for arthrodesis of the posterior facet of the subtalar joint. Autogenous bone from the tibia was used for the fusion (84). Several authors used this same technique (79–81).

Arthrodesis of the subtalar joint continues to be a popular procedure for end-stage articular disease of the subtalar joint secondary to calcaneal fractures, and it usually results in a good predictable functional outcome, provided the patient has no symptomatic involvement of the calcaneocuboid joint. If significant joint depression is evident, then a bone graft may be inserted into the posterior facet of the subtalar joint in conjunction with the fusion. This approach increases calcaneal height, increases the lateral talocalcaneal angle, and, more important, decreases anterior ankle joint impingement (85). Several other authors have reported good results with this technique (86–90). Alterations in the graft shape can also decrease varus or valgus alignment of the os calcis. Distraction arthrodesis of the subtalar joint has been advocated by some surgeons as the primary procedure for intraarticular calcaneal fractures when there is significant comminution and significant loss of articular surface (91).

Arthrodesis of the subtalar joint has also been proposed for the treatment of paralytic pes valgus deformities in children and adolescents. Chambers, who placed an opening bone graft beneath the lateral portion of the posterior facet of the subtalar joint, first described extraarticular control of the subtalar joint (92). Theoretically, this procedure prevented pathologic subtalar joint pronatory motion and stabilized the joint without compromising all motion at the joint. In 1943, Hohmann used the same lateral approach and performed an "extraarticular" arthrodesis of the subtalar joint (93).

Through a series and publication with Green, Grice pop-

ularized the same procedure in the English-language literature. Grice described extraarticular fusion of the subtalar joint in which the calcaneus was placed beneath the talus with the foot held in a plantarflexed position. The subtalar joint was then fixed in this position with tibial bone graft placed in the sinus tarsi area. This approach allowed for correction of deformity and maintenance through arthrodesis without significantly effecting remaining bone growth (94–96). Several authors have used this technique with varying degrees of success (97–113). Many modifications have been made with regard to fixation and bone grafting techniques to ensure successful arthrodesis.

Good results have also been reported with isolated subtalar joint arthrodesis for treatment of pronated feet of nonparalytic origin (61,63,68,69,72–74,114–116). Specifically, arthrodesis of the subtalar joint is effective on a long-term basis for the treatment of multiplanar deformities of the rearfoot complex including significant collapsing pes valgo planus deformities secondary to tibialis posterior tendon dysfunction (61,68,69).

Indications

The two most common disorders for which an isolated subtalar fusion is performed are an *old calcaneal fracture* without significant clinical and radiographic involvement of the calcaneocuboid joint or significant varus heel alignment and *acquired adult pes valgus deformity* secondary to tibialis posterior tendon disease (72,74,116) (Fig. 37). The third most common cause of a subtalar joint fusion has been *symptomatic talocalcaneal coalition* (72,74).

Other conditions that may benefit from arthrodesis of the subtalar joint are subtalar joint instability (chronic inversion sprains), some cavovarus foot deformities (usually in conjunction with a first ray procedure and other soft tissue muscle tendon releases or balancing procedures), inflammatory arthritis, intraarticular bone or soft tissue tumors of the talus or calcaneus, chronic infection localized to the subtalar joint, intraarticular fractures of the talus or calcaneus with arthritis, residual talipes equinovarus, neurologic pes valgus deformities such as cerebral palsy, collapsing pes valgo planus deformities, and chronic pain without an identifiable source. In general, the disorder should be localized or primarily focused at the subtalar joint without any clinical evidence of midtarsal joint arthritis or rigidity. Primary arthritis of the subtalar joint, without history of calcaneal fracture, has also been cited as a significant indication for fusion of the subtalar joint (72).

We believe that primary arthritis of the subtalar joint is seen in two distinct types. The first type is usually seen after an isolated "ankle sprain" or chronic ankle sprain injuries (117). Patients are treated conservatively, but they do not really have significant improvement. On magnetic resonance imaging examination, significant violation of the ligaments of the sinus tarsi with or without subchondral marrow edema is often evident. This may represent a subtalar sprain or even subluxation or dislocation of the subtalar joint with spontaneous reduction. In a magnetic resonance imaging evaluation of 123 patients after an "ankle sprain," Klein et al. demonstrated that 33 of these patients had associated or primary inflammation of the sinus tarsi. Seven of those 33 patients had no involvement of the lateral collateral ligaments (118). This finding may indicate a primary subtalar sprain, subluxation, or dislocation. Unfortunately, many of these patients are managed as though they had an ankle sprain, and ambulation may be permitted on an unstable subtalar joint (Fig. 38).

In the second type of patient who demonstrates primary arthritis of the subtalar joint, the disease is the result of biomechanical problems involving the lower extremity. Subsequent pronatory compensation for deformities such as a rigid forefoot varus or tibial varum cause maximal pronation of the subtalar joint. Often, these patients have no clinical appearance of a pes valgus deformity, and the tibialis posterior tendon is uninvolved. Patients who function in a maximally pronated position may develop degenerative joint disease of the subtalar joint. These patients do well with an isolated subtalar joint arthrodesis.

Another concern about isolated subtalar joint fusions is the ability to restore congruity to the talonavicular joint. In one study, talonavicular congruity increased from 62% to 93% after subtalar arthrodesis with an average follow-up of 38.5 months (68). Once the calcaneus is placed beneath the talus after fusion of the subtalar joint, the axes of the talonavicular and calcaneocuboid joints assume an oblique orientation to each other, and midtarsal joint motion is restricted (61,63,119–124). Otis et al. demonstrated a statistically significant decrease in size of the spring ligament after isolated subtalar joint fusion. However, these investigators showed no improvement with respect to load protection for the spring ligament after subtalar joint arthrodesis (125). Therefore, if the midtarsal joint is stable with the subtalar joint held in a corrected position on the preoperative clinical examination, then the midtarsal joint should be stable after subtalar joint arthrodesis. The foot tends to maintain position because of the structural and functional interaction between the subtalar joint and the midtarsal joint, when the subtalar joint and midtarsal locking mechanism are intact. This situation has been demonstrated by maintenance of navicular height and improved talonavicular articulation when the subtalar joint is repositioned with arthrodesis (61,68,69).

Although fusion of the subtalar joint complex reduces normal shock absorption with heel impact, one must remember that in patients with significant pes valgus deformity, this function has, more often than not, already been eliminated. These patients usually strike with the heel in valgus in contradistinction to that of a normal subtalar joint. Patients do not report significant symptoms of stiffness or other postural complaints related to the knee, hip, or lower back segments after the procedure. Although motion in the midtarsal joint is clearly decreased in most cases, the motion that does remain seems to be beneficial in gait.

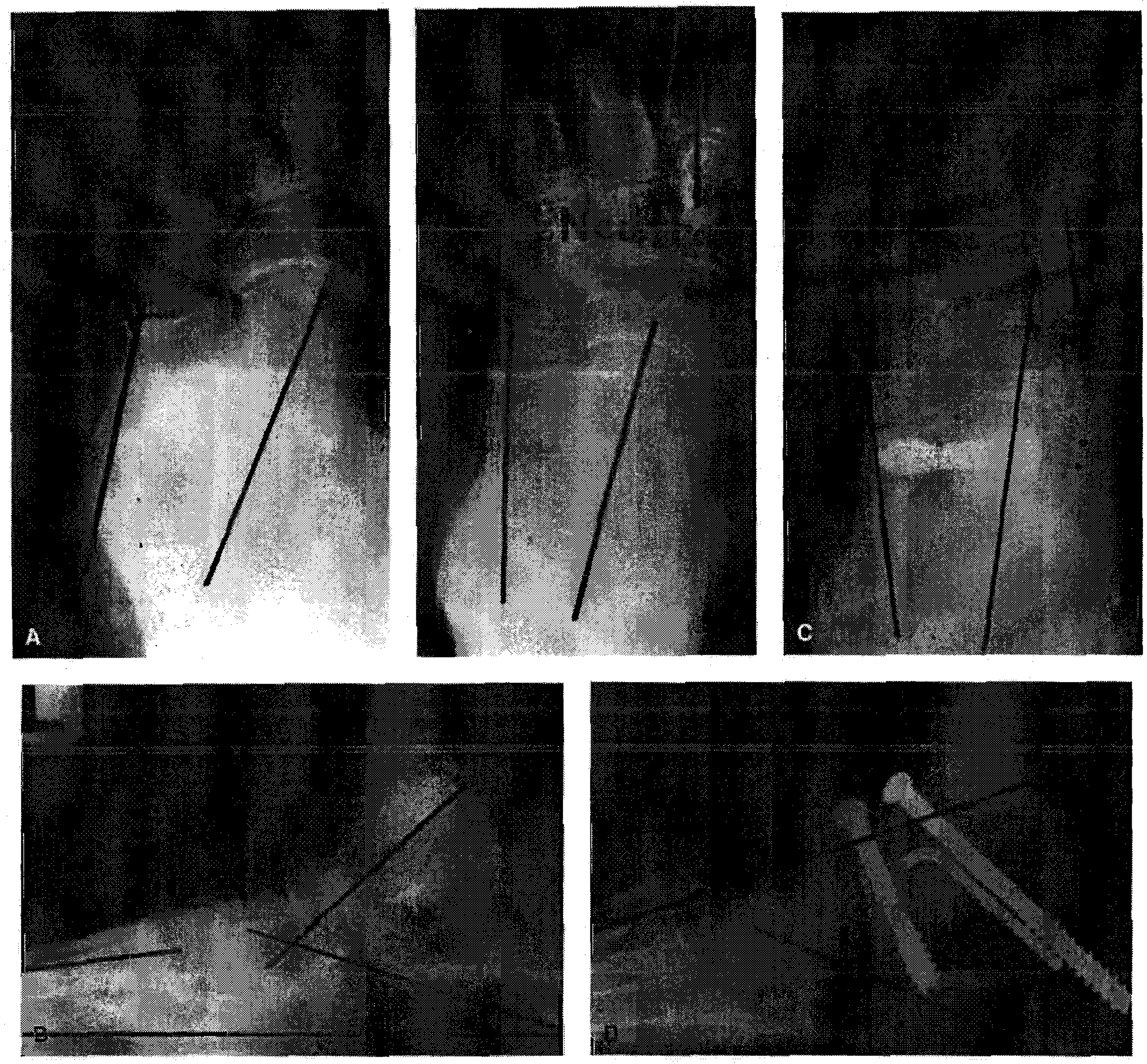


FIG. 37. Preoperative dorsoplantar **(A)** and lateral **(B)** radiographs of a patient with an adult-acquired pes valgus deformity. Notice the extent of subtalar joint pronation and the lack of talonavicular congruity. Postoperative dorsoplantar **(C)** and lateral **(D)** radiographs of the same patient after subtalar joint arthrodesis for correction of multiplanar deformity. Notice the excellent restoration of alignment to the subtalar and midtarsal joints as determined by radiographic criteria such as the talocalcaneal angle, talar declination, talonavicular congruity, and cuboid abduction angles.

Surgical Technique

A standard lateral incision is made from the tip of the fibula to the base of the fourth and fifth metatarsal cuboid articulation. The incision should be just superior to the sural nerve and peroneal tendons. Dissection is performed through the subcutaneous tissue to the layer of deep fascia, along the entire incision. At the proximal half of the wound, one may encounter communicating branches between the sural nerve and intermediate dorsal cutaneous nerve. If a communicating nerve branch is present, it is usually excised to facilitate dissection and exposure. Often, when an attempt is made to spare this nerve, retraction on this structure may cause transient neuropraxia or chronic neuritis.

During dissection, care should be taken to preserve the peroneal tendon sheath and the thin, yet distinct retinaculum overlying the muscle belly. Once the retinaculum of the extensor digitorum brevis muscle has been identified, complete

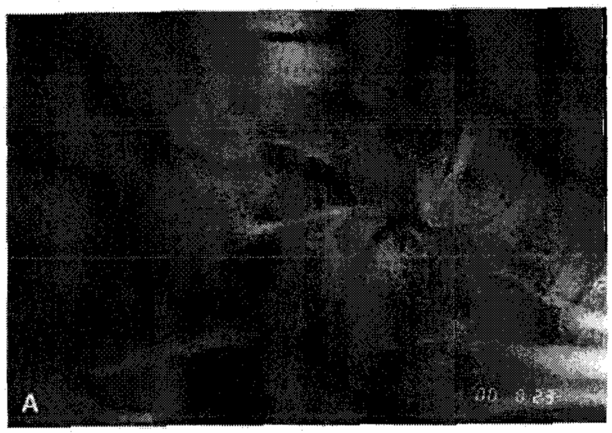
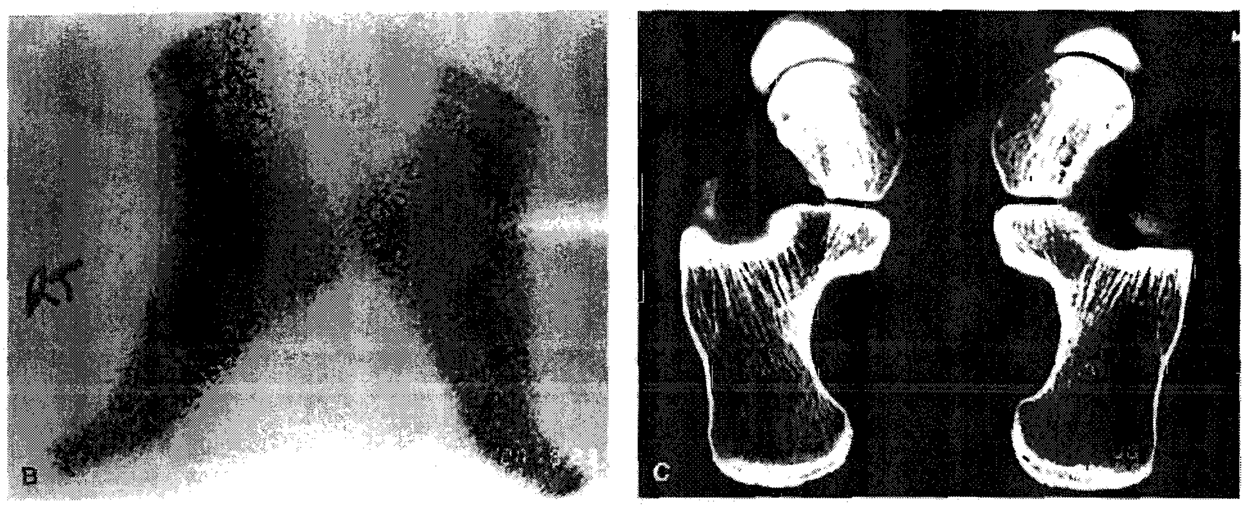


FIG. 38. **A:** Lateral radiograph of a patient who sustained a severe inversion ankle sprain with persistent pain, muscle splinting, and spasm in spite of aggressive conservative therapy. Before this episode, the patient had no complaints of symptoms within the foot. **B:** Conventional bone scan of the same patient showing increased focal uptake within the subtalar joint complex. This correlates with the clinical findings and observations as well as the subjective complaints. **C:** Computed tomography scan of the same patient did not demonstrate any joint pathology specific to the subtalar joint; no evidence of coalition was found. Recommended treatment for this patient was primary subtalar joint arthrodesis, which provided full relief and 100% functional return to normal activity; complaints of instability and pain totally resolved.



separation between the superficial fascia and the deep fascial layer is easily performed with blunt dissection. At this point, manipulation of the subtalar joint can be performed to identify the lateral process of the talus, the sinus tarsi, and the floor of the sinus tarsi (superior aspect of the calcaneus). This ensures appropriate placement of the deep fascial incision.

A vertical incision is made into the deep fascia at the level of the sinus tarsi, just anterior but parallel to the leading edge of the lateral process of the talus. Once the blade reaches the superior portion of the calcaneus, the vertical arm of the deep fascial incision is completed. The distal half of the longitudinal deep fascial incision is then performed, at the junction of the extensor digitorum brevis muscle belly and deep fascia overlying the peroneal tendons. Before this longitudinal incision, the extensor digitorum brevis muscle belly may be lifted off the deep capsular periosteal tissues overlying the distal calcaneus and cuboid. Alternatively, a linear incision may be made through the inferior portion of the extensor digitorum brevis muscle belly.

After these steps are taken, the posterior facet of the subtalar joint and lateral process of the talus can be visualized through the vertical deep fascial incision. The corner of this inverted-L incision is then raised sharply with a No. 15 blade. The contents of the sinus tarsi are then evacuated with a small, straight rongeur or by sharp excision. The cervical and bifurcate ligaments may then be identified. The cervical ligament and the attachment for the lateral portion of the extensor retinaculum are sacrificed by sharp dissection from the superior and distal aspect of the calcaneus. One may attempt to preserve the attachments of the bifurcate ligament. The extensor digitorum brevis muscle belly, underlying periosteum, and ligamentous structures, as well as the overlying retinaculum, are raised in one layer. If desired, lateral to medial dissection may be performed to expose the middle facet deep within the sinus tarsi.

To gain adequate exposure to the posterior facet for joint resection and subsequent positioning, the longitudinal deep fascial incision is extended proximally, to include the lateral periosteal, capsular, and ligamentous structures of the posterior facet and subtalar joint. The peroneal tendons are identified by a stab incision into the overlying sheath and retinaculum at the tip of the fibula. The tendons are visualized and are retracted laterally. The medial portion of the peroneal tendon sheath and retinaculum, the lateral talocalcaneal and

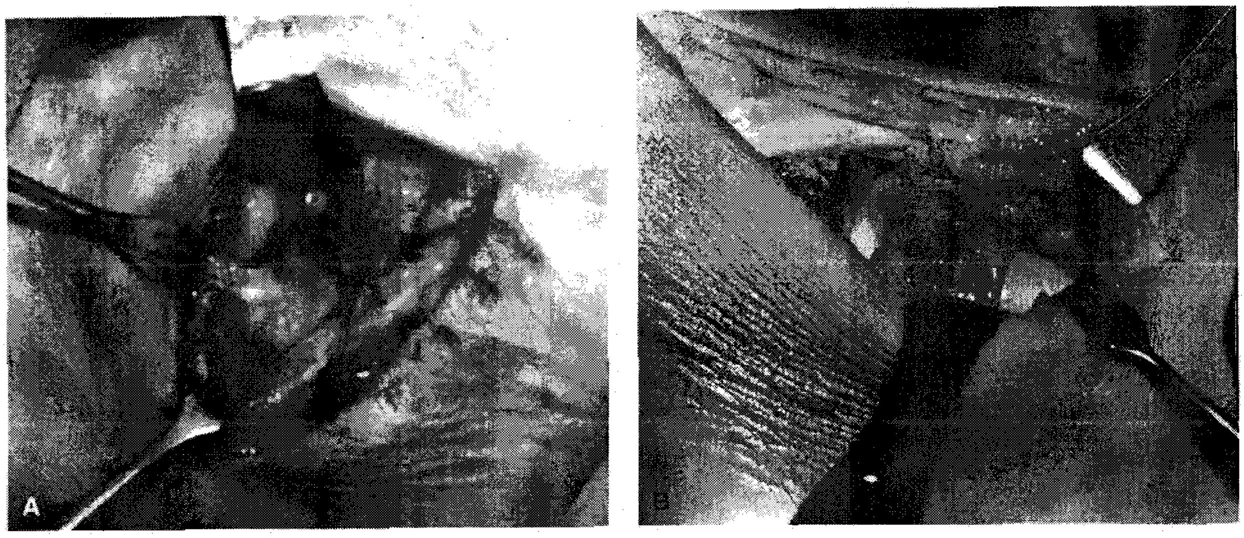


FIG. 39. Surgical dissection from a lateral and medial approach for visualization of the entire subtalar joint complex and sinus tarsi area including the posterior and middle facets. **A:** Lateral exposure. The ligaments of the sinus tarsi are completely excised. The calcaneal fibular ligament may also be released for visualization of the posterior facet of the subtalar joint. **B:** Medial exposure. The talar head and neck as well as the medial articular surface are visualized for accurate fixation of the subtalar joint. Visualization of the talonavicular joint is not necessary. This approach also allows ready resection of any talar or navicular exostosis not uncommonly present.

calcaneofibular ligaments, and the lateral talocalcaneal capsule are then incised sharply. Specialized instruments such as Crego elevators may be helpful to ensure complete release of the periarticular tissue around the posterior facet of the subtalar joint. After completion of the deep fascial dissection, it should be easy to sublux the subtalar joint for joint resection and subsequent repositioning (Fig. 39).

When isolated subtalar joint arthrodesis is performed for an old calcaneal fracture, or in a patient with significant arthritis of any cause, it is sometimes difficult to open the joint because of periarticular fibrosis and severe degeneration of the joint. In these instances, it is often advantageous to insert a large blunt instrument and pry the joint apart. A Sayre or Joker-type elevator is useful in these situations. If this maneuver fails, use of the Synthes minidistractor, with one or two pins in the lateral talar body and one or two pins in the lateral calcaneus, allows distraction and subsequent visualization of the posterior facet of the subtalar joint. Laminar spreaders and similar instrumentation can also be used to distract the joint (Fig. 40). In this situation, consideration may be given to multiple, dowel grafts at the joint level or an *in situ* type of fusion because this technique does not require distraction of the joint. Osteocartilaginous plugs, at the level of the posterior facet, are removed using bone trephines or large Craig bone biopsy needles. These plugs can be rotated 90 degrees and can be converted to rotational inlay grafts. However, we prefer to remove the plugs completely and to fill their voids with a bone graft substitute, allograft composite, or autogenous cancellous bone graft harvested from the posterior aspect of the calcaneus or perhaps the medial distal tibia.

If placement of the bone trephine or biopsy needle across the entire lateral to medial excursion of the posterior facet is difficult, then the trephine hole may be deepened with a round or side-cutting bur, once the plug at the joint level has been started. When an *in situ* rotational graft fusion is performed, the position of the foot should be acceptable preoperatively because no positional changes are possible with this technique.

Cartilage removal can be accomplished using multiple instruments, including small and large solid curettes, ring curettes, straight and curved osteotomes, rongeurs, No. 15 blades, power saws, and rotary burs. Once all the cartilage is removed from both sides of the subtalar joint, the surfaces can be fenestrated with a small drill bit (Fig. 41). This method is preferred by some surgeons. Alternatively, the joint surface may be further reduced to adequately bleeding bone with a rotary bur. This maneuver, in essence, removes the subchondral bone plate. In either instance, an attempt is made to maintain the anatomic contours of the joint. This facilitates apposition of the surfaces and allows the deformity to be corrected by pronation and supination of the joint. Regardless of the specific technique employed, all cartilage must be removed to ensure radiographic and clinical fusion.

After joint preparation is complete, the next and most important step in this procedure is positioning of the subtalar joint. The subtalar joint is placed in neutral to slight

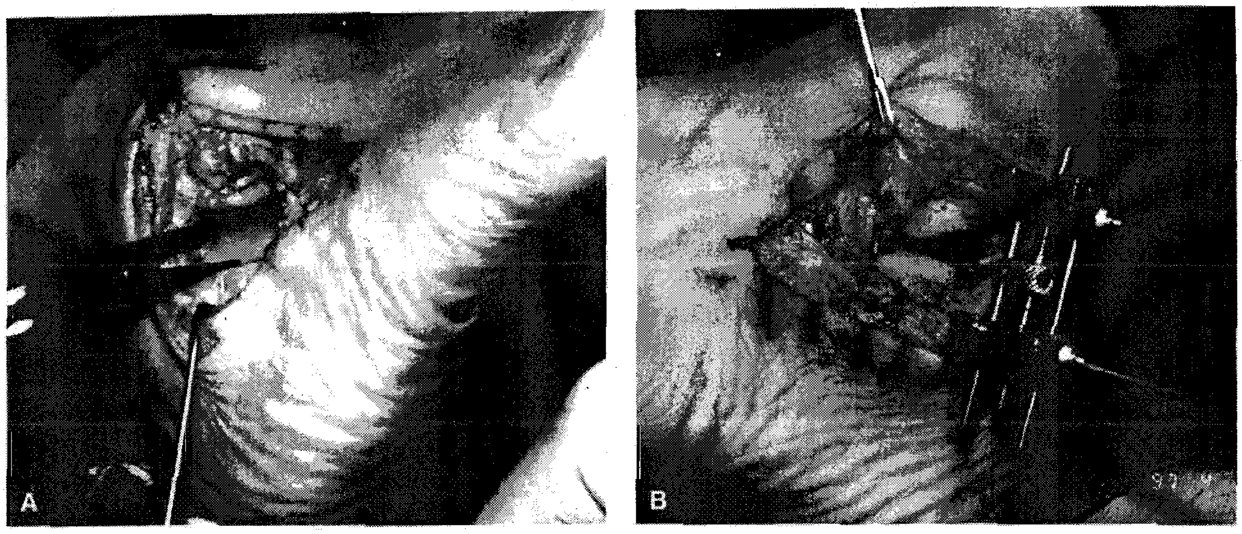


FIG. 40. A: Distraction of the subtalar joint using a spinal distractor. This instrument maintains distraction without compromising visualization of the articular surfaces for resection. **B:** Distraction of the subtalar joint using a Synthes miniature distractor, which employs up to four Steinmann pins to maintain position while resection of the joint is performed.

valgus position. Obviously, it is important to avoid fusing the subtalar joint in a supinated attitude because this can be as significant as or even more problematic than valgus positioning.

The difficulty is not in deciding where the subtalar joint should be placed, but in how to achieve this neutral position objectively and repeatedly. Complete posterior facet congruity may serve as a marker for a neutral subtalar joint. Likewise, a supinated attitude of the subtalar joint may be appreciated when posterior subluxation of the talar portion of the joint is seen. A pronated attitude of the joint may be appreciated when the anterior aspect of the lateral talar process rests in the floor of the sinus tarsi. Somewhere in between these two end points, neutral is reached. This may be correlated with the alignment when the posterior heel is held in the cupped hand.

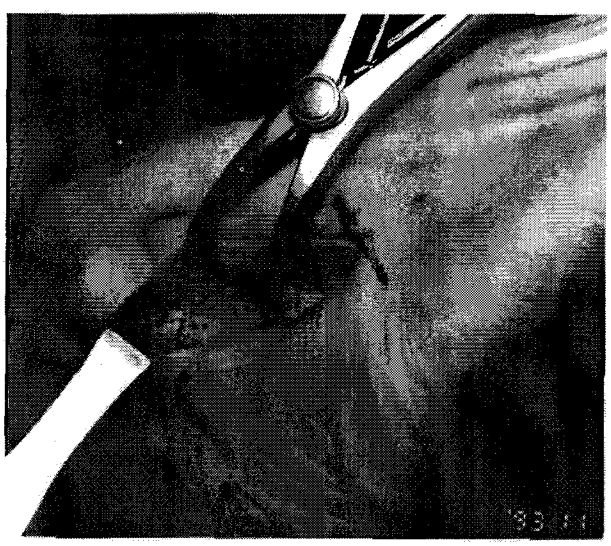


FIG. 41. Visualization of the posterior facet of the subtalar joint with fenestration through adjacent surfaces using a small drill.

Another technique for assessing the neutral position of the subtalar joint is simply to allow the foot to hang off the table or a stack of towels. The heel usually hangs in a close to neutral position. The forefoot is then loaded by dorsiflexing the lesser metatarsals and the ankle in one maneuver. If this is done without inverting or everting the heel (i.e., without supinating or pronating the subtalar joint), the foot should be in a neutral position.

With experience, surgeons develop their own preferred techniques with respect to positioning one or all of the joints of the rearfoot before an arthrodesis procedure. When questions exist about position, temporary fixation can be achieved and the joint can be evaluated with intraoperative fluoroscopy or plain radiographic evaluation. Ultimately, the physician's clinical "feel" plays the greatest role in positioning the subtalar joint before arthrodesis.

Fixation

The type of *fixation* employed varies with the site of fusion and the individual preferences of the surgeon. As a general rule, rigid internal fixation is preferred whenever possible. Isolated subtalar joint arthrodesis has most commonly been accomplished by the use of a single large cancellous screw, most commonly inserted through the neck of the

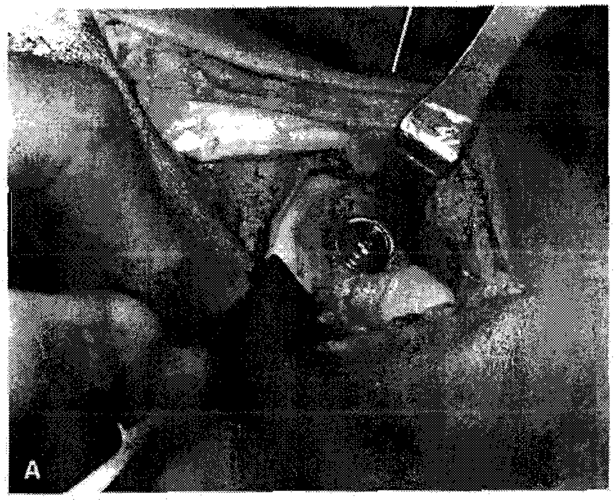
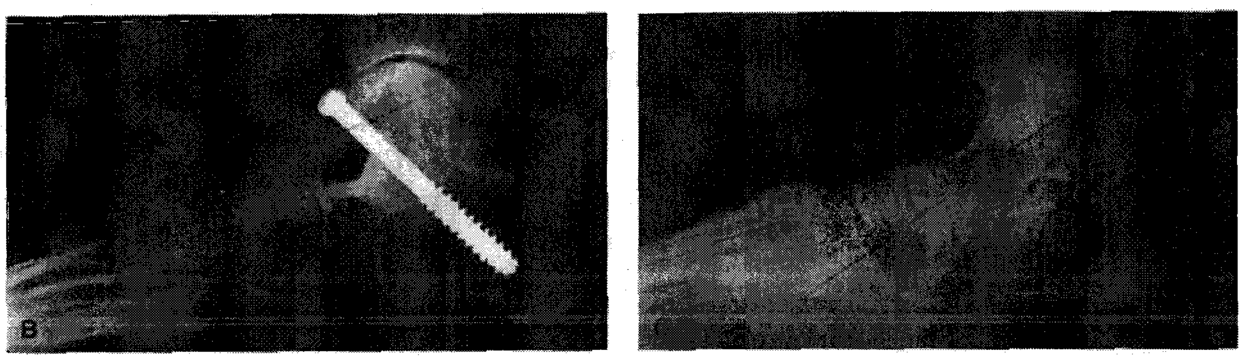


FIG. 42. A: Intraoperative photograph showing fixation of the subtalar joint with one large cancellous screw with a washer because of the soft nature of the bone at the neck of the talus. This approach can also be required if aggressive countersinking is performed. **B:** Lateral radiograph of the same patient with an isolated subtalar joint fusion. Note excellent osseous bridging. **C:** Preoperative lateral radiograph of a patient with a pes valgus deformity.



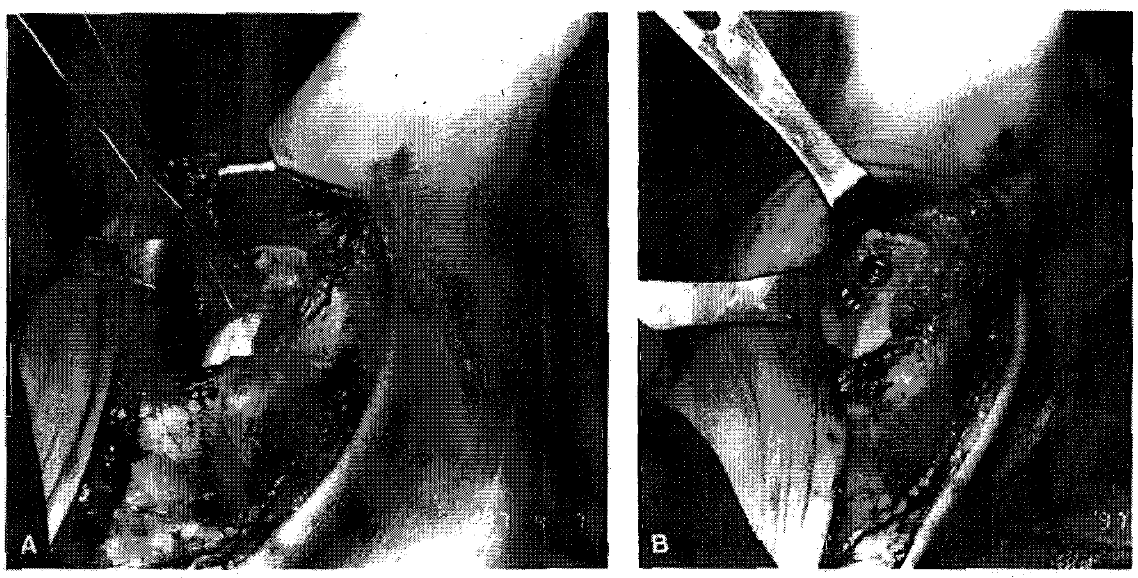
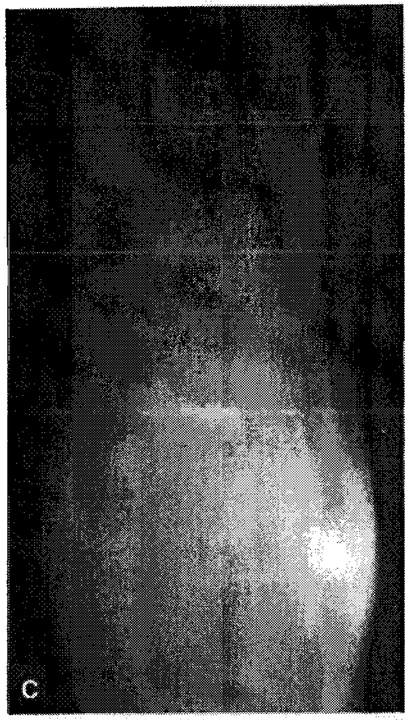


FIG. 43. A: Intraoperative photographs demonstrating the two-screw technique for stabilization of the subtalar joint. Notice the presence of the two guidewires in place. Radiographic confirmation is obtained before final insertion of the screws. **B:** The same patient demonstrating both screws in the talar neck after insertion. *(continued)*



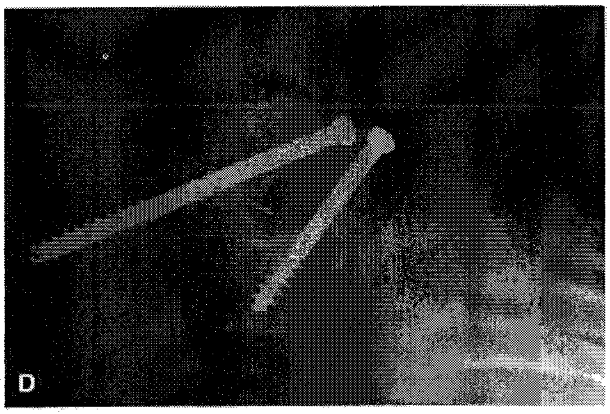


FIG. 43. *Continued.* Postoperative dorsoplantar **(C)** and lateral **(D)** radiographs of the same patient.

talus into the body of the calcaneus. This screw crosses the posterior facet of the subtalar joint (Fig. 42). Alternatively, the screw may be oriented from inferior to superior through a small stab incision along the posterior inferior aspect of the heel. The primary advantage to this latter approach appears to be the avoidance of medial dissection needed to expose the neck of the talus for screw insertion. This may be of benefit in patients with compromised soft tissue around the anterior and medial ankle. However, when the screw has been inserted from an inferior approach, it is not uncommon to require subsequent removal for overt irritation as a result of prominence of the screw head or persistent, inexplicable discomfort even when the screw head is buried flush with the cortical surface of the calcaneus.

A double-screw technique may also be employed. The screws may be of equal size, or if preferred, the second screw may be of smaller diameter. If the second screw is placed across the middle facet and as far distal to the standard posterior facet screw, greater rotational stability will be achieved (Figs. 43 and 44).

If the physician wants to avoid a secondary incision but does not favor placing a screw head in the inferior portion of the calcaneus, lateral staple fixation is also a viable alternative. Should screws or staple fixation not be possible, then stabilization with one or more wires will likely be adequate.

We previously reported on another simple technique to facilitate positioning in surgery that involves the use of a Kirschner wire or a Steinmann pin within the sinus tarsi area. This device is placed parallel to the leading edge of the lateral process of the talus and perpendicular to the posterior facet of the joint once the desired position of fusion is determined. It is driven into the calcaneus, but not the talus, and it serves to block plantar deviation or pronatory motion during fixation and postoperatively if it is left in place permanently. It functions, in essence, as an arthroereisis device around a single point of fixation of the subtalar joint (126) (Fig. 45).

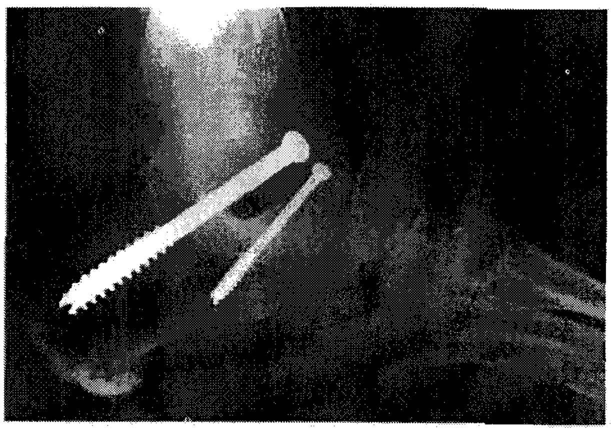


FIG. 44. A lateral radiograph demonstrating fixation of the subtalar joint using a two-screw technique. One large cancellous screw and a secondary smaller 4.0-mm cancellous screw have been employed.

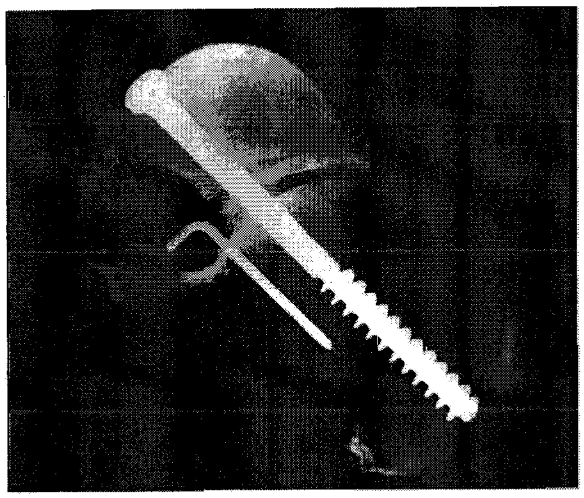


FIG. 45. Cadaveric bone specimen and corresponding lateral radiograph demonstrating the technique of one large cancellous screw with the use of a Kirschner wire at the anterior leading edge of the lateral process of the talus within the sinus tarsi area to serve as a physical block for the subtalar joint. This pin may be bent as demonstrated and left in place postoperatively, or it may be used for temporary measuring during surgery to preserve alignment and position.

TALONAVICULAR JOINT ARTHRODESIS

Historical Review

An *isolated talonavicular joint arthrodesis* has predominately been performed for pes valgus deformity, patients with rheumatoid arthritis, patients with flexible feet and posttraumatic conditions (57,65,66,70,127–135). Initially, this procedure was advocated for children with a severely pronated foot. Ogston offered of the first paper on talonavicular joint arthrodesis in 1884. He described good results in 16 of 17 patients (136). Subsequently, talonavicular arthrodesis was advocated for the treatment of collapsing pes valgo planus deformity in children (137–139). Ogilvy reported good results in 94% (66 of 70) of his patients after talonavicular fusion. Two of the 6 failures were secondary to nonunion and, in general; poor results were attributed to premature weight bearing and performance of procedure on patients in the age range of 5 to 7 years (137).

In adults, fusion of the talonavicular joint has been primarily performed in patients with rheumatoid arthritis. Several investigators reported good long-term results after talonavicular joint arthrodesis in patients with flexible feet and disease localized to the talonavicular joint (130,132–135, 140). Elbar et al. reported on 31 patients with 35 fusions with an average follow-up of 5 years, ranging from 1 to 13 years. Complete resolution of hindfoot pain was appreciated in 75% (26 of 35) of the patients, and 89% of the patients had an improved gait postoperatively (134). Dalziel et al. described findings in 101 fusions of the talonavicular joint in 97 patients with an average follow-up of 52 months. Good to excellent pain relief was seen in 95% of the patients, and the authors contended that "the operation maintains hindfoot alignment and prevents a progressive valgus heel deformity from occurring" (133). Although studies have demonstrated moderate to significant restriction of subtalar joint motion after the procedure, in one report some patients could still participate in golf, tennis, and jogging (130). Isolated talonavicular arthrodesis has also been used with success for patients with an acquired pes valgus deformity secondary to tibialis posterior tendon dysfunction (66) (Fig. 46).

Indications

The most common indication for an isolated talonavicular joint arthrodesis has historically been arthrosis in patients with *rheumatoid arthritis.* This procedure has also been used more recently for the treatment of flexible deformities associated with tibialis posterior tendon dysfunction. Other entities that affect the articular or subchondral portions of the talonavicular joint also merit consideration for an arthrodesis. Most notably, this includes late sequelae from a stress fracture of the navicular or Kohler's disease. In these situations, double joint fusion including the naviculocuneiform and talonavicular joints may be needed. The procedure may also be considered for the repair of pes valgus deformity in children, adolescents, or adults. Talonavicular arthrodesis may be combined with an Evans calcaneal osteotomy in patients in whom medial column osteotomy or tendon procedures (i.e., Young's procedure) would prove inadequate to resolve forefoot varus. In addition, the procedure may be considered in patients with a collapsed pes valgus deformity with a flexible midtarsal joint, but whose subtalar joint is not sufficiently flexible for an Evans osteotomy with graft.

Surgical Technique

The talonavicular joint is approached through a linear incision overlying the talus and navicular that extends from the tip of the medial malleolus to the level of the medial cuneiform. This incision essentially bisects the medial longitudinal arch. Key structures include the tibialis anterior tendon, the greater saphenous vein and nerve, the medial malleolus, the medial gutter, the talar head, and the navicular tuberosity. By a combination of sharp and blunt dissection, the incision is carried down to the level of the deep fascia, periosteum and capsular tissues. Tributaries branching from the inferior aspect of the saphenous vein are ligated, and the vein and nerve are retracted dorsally and laterally.

With passive range of motion and manipulation of the foot, one may readily appreciate the talonavicular joint. The deep fascia and periosteum are then incised from the medial gutter area of the ankle across the talus and the navicular, and the incision terminates on the medial cuneiform. The dorsal tissue are dissected from the talus and navicular as far laterally as possible. During the course of the dorsal lateral dissection, the synovial fold of the talonavicular joint should

FIG. 46. Preoperative dorsoplantar **(A)** and lateral **(B)** radiographs of a patient with adult acquired pes valgus deformity. Notice the extent of the subtalar joint pronation and the lack of talonavicular congruity. Postoperative dorsoplantar **(C)** and lateral **(D)** radiographs of the same patient after subtalar joint arthrodesis for correction of multiplanar deformity. Notice excellent restoration of alignment to the subtalar and midtarsal joints as determined by radiographic criteria such as the talocalcaneal angle, talar declination, talonavicular congruity, and cuboid abduction angles.

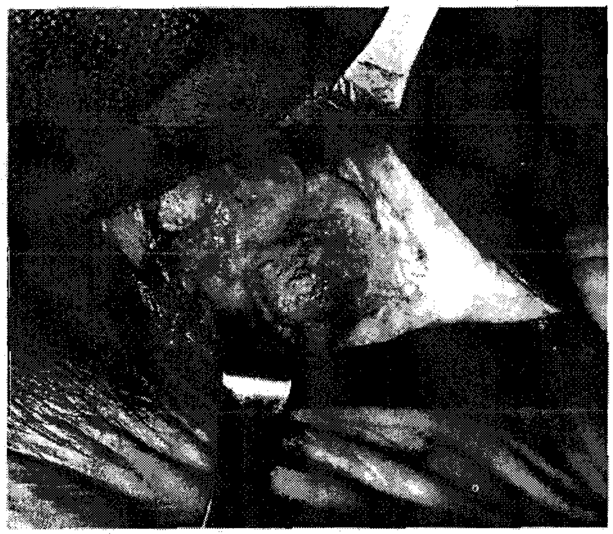


FIG. 47. Exposure of the talar head and neck and the navicular providing complete access to the joint. Subperiosteal dissection should be performed to prevent any periarticular structures from limiting the exposure of the joint with attempted distraction.

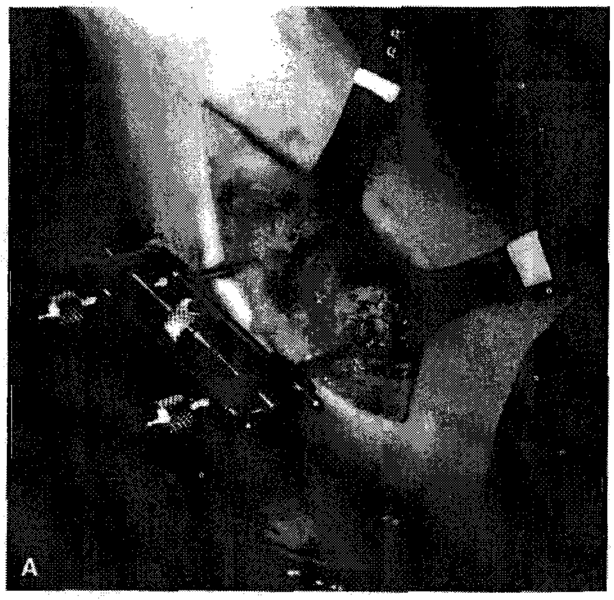
be easily identified. Special instrumentation including Crego elevators and Army Navy retractors are helpful in raising the dorsal tissue to facilitate sharp dissection. Subperiosteal dissection and subcapsular dissection are then performed along the medial aspect and plantar aspect of the talus and navicular to ensure easy distraction of the joint for resection of the cartilage. Medially, if an os tibiale externum is present, it may be readily extirpated from within the periosteal flap of tissue. If the navicular tuberosity is exceptionally large or gorillaform, it can be resected and remodeled (Fig. 47).

During isolated fusion of the talonavicular joint with preservation of the subtalar and calcaneocuboid joints, a curettage technique to remove cartilage tends to reduce the shortening of the medial column. Achieving a "neutral" position of the joint, and thus the foot, may be easier, and adjustments in position are more readily accomplished. A miniature linear distractor or laminar spreader may be employed to distract the joint. In some cases in which extreme mobility or flexibility is present, the talonavicular joint can be easily dislocated to provide exposure of the adjacent surfaces. Cartilage removal is accomplished using a combination of standard and ring curettes or rongeurs along with a power bur (Fig. 48). If a power saw is used for the joint resection, shortening may be controlled by maintaining the foot in the desired position of correction during resection of the joint surfaces to enhance fit of the fusion surfaces.

The joint is then placed in the desired position of correction. Congruity in both transverse and sagittal planes is the main goal. Concentration in the transverse plane is responsible for correction of abduction deformity, whereas sagittal plane focus corrects for the height of the medial longitudinal arch. Proper position is confirmed by dorsoplantar and lateral intraoperative radiographs after temporary fixation with a Kirschner wire or a Steinmann pin.

Fixation

The talonavicular joint may be effectively *stabilized* for arthrodesis in several ways. A single large screw, such as



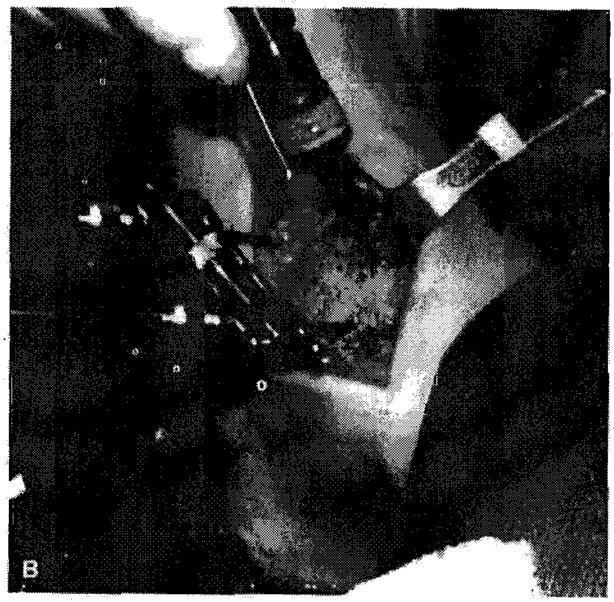


FIG. 48. A: Complete distraction of the talonavicular joint demonstrating removal of the cartilage from both the head of the talus and the body of the navicular. Notice the preservation of the convexity of the talar head and concavity of the navicular. **B:** Subchondral drilling performed before fixation of the joint.

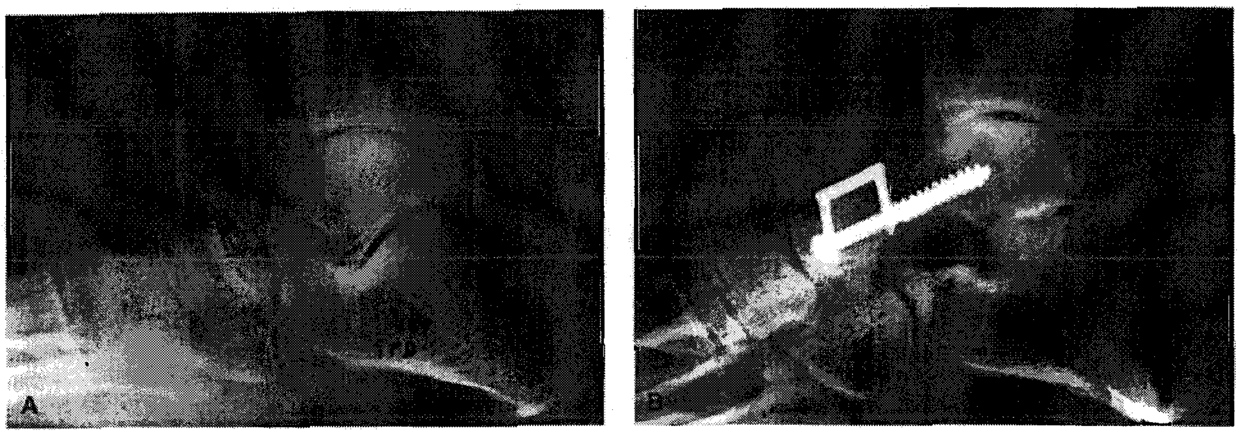


FIG. 49. Preoperative **(A)** and postoperative **(B)** lateral radiographs showing stabilization arthrodesis of the talonavicular joint with one large cancellous screw and large barbed staple.

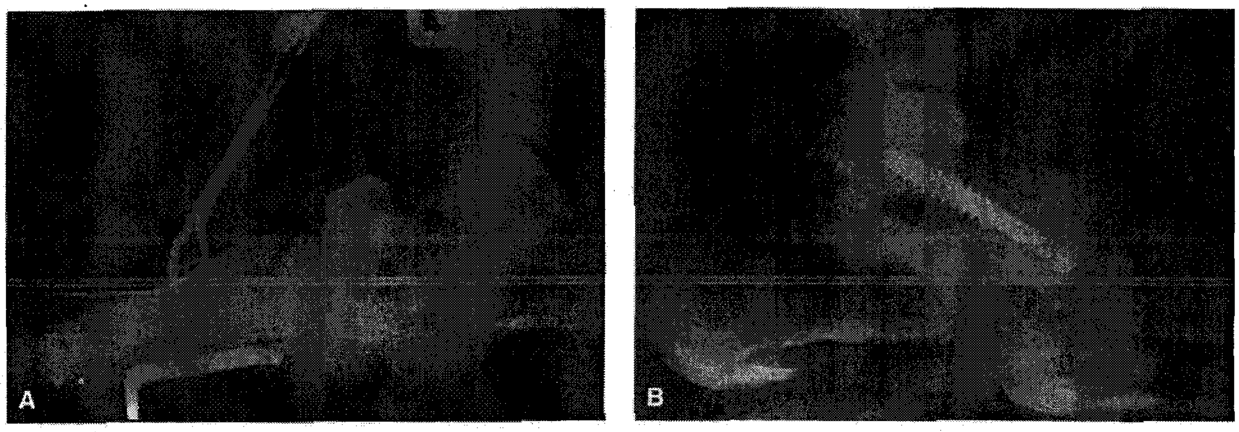


FIG. 50. Talonavicular fusion may be accomplished with staple fixation **(A)** or with a single large screw **(B).**

a 6.5-mm screw, provides excellent stability. The screw is directed from the distal aspect of the navicular immediately adjacent to the medial surface of the medial cuneiform and is driven proximally into the head and neck of the talus, progressing from medial to lateral. It terminates with the lateral half of the body of the talus.

One may augment this fixation with a staple or smaller screw if deemed necessary (Fig. 49). Multiple smaller screws or staples can also be successfully employed. When one uses staples, two devices are typically employed, with one inserted from medial to lateral and the other from dorsal to plantar. Prior experience and personal preference influence the final choice of fixation materials and methods (Fig. 50).

CALCANEAL CUBOID JOINT ARTHRODESIS

Historical Review

The use of *isolated calcaneocuboid arthrodesis* to address instability and deformity of the rearfoot-midfoot complex has evolved from surgery of the neglected or relapsed clubfoot. The work of Evans, which placed emphasis on lateral and medial column balance, has afforded the most insight for the application of calcaneocuboid fusion. Evans believed that the primary deformity in a residual clubfoot was seen at the level of the midtarsal joint, and the remaining components of the deformity (heel varus) were secondary and adaptive. In combination with appropriate soft tissue releases, Evans performed resection arthrodesis of the calcaneocuboid joint, to reduce indirectly and maintain what he believed was the primary component of the deformity at the midtarsal joint–medial navicular dislocation (141). This view was supported by other surgeons as well (142–145).

Historically, many authors recognized the need to remove bone from the lateral column during treatment of a residual clubfoot deformity. This type of procedure usually involved removing part of the distal calcaneus or cuboid, in conjunction with a posteromedial soft tissue release, to relocate the navicular in front of the talus (146–151).

Evans used fusion after wedge resection of the calcaneocuboid joint to provide a complete and permanent correction. Good subtalar mobility was maintained after the procedure, and the varus malalignment of the heel was reduced in conjunction with a soft tissue release medially. However, Evans believed that the varus reduction was predominantly the result of the lateral fusion (141). Common complications were overcorrection and the creation of an abducted midfoot and valgus heel (149,152,153). Evans addressed the overcorrection (calcaneal valgus) with an opening wedge bone graft in the distal lateral calcaneus.

In 1975, Evans published a follow-up article describing the efficacy of placing an opening wedge bone graft in the distal calcaneus to correct a flatfoot deformity in the transverse tarsal joint (153). Several studies have shown the long-term effectiveness of this procedure when treating a flexible pes valgus deformity in a child (154–157), and many authorities consider an opening wedge osteotomy of the calcaneus to be the primary procedure when osseous work is deemed necessary in pediatric patients (154–160). This type of osteotomy and bone grafting procedure allows for correction of forefoot abduction and heel valgus by limiting midtarsal pronation. Basically, the calcaneus is lengthened, and direct support is afforded to the head of the talus, which prevents plantarflexion and adduction of the talus. Ultimately, the subtalar-midtarsal locking mechanism is restored, and the foot is functionally secured to the leg by the talus. Clinically and radiographically, this is most evident by restoration of the talonavicular articulation. As in the Evans clubfoot procedure, motion at the subtalar joint is largely preserved.

Hansen (67,161) took the concept of lateral column lengthening as a stabilization procedure one step further. He proposed lateral column lengthening using an interpositional bone graft at the calcaneocuboid arthrodesis site for the adult acquired pes valgus deformity. Fusion of the joint with lengthening was favored, as opposed to extraarticular osteotomy, owing to concern regarding the potential for osteoarticular changes at the calcaneocuboid joint. In a cadaveric model, Cooper demonstrated that excessive loads are transferred to the calcaneocuboid joint, after 10 mm of lengthening (162), and long-term follow-up of the Evans osteotomy showed osteoarthritic changes confined to the calcaneocuboid joint (156). Hansen theorized that the transversely oriented joints of the midtarsus and lesser tarsus (calcaneocuboid, second and third naviculocuneiform, and tarsometatarsal joints) were "nonessential" and could be sacrificed to achieve stability without compromising hindfoot kinematics (58). In one study, calcaneocuboid arthrodesis was shown to have little effect on subtalar joint motion, and it decreased the talonavicular joint mobility only by a mean of 33% (163). However, other investigators reported 52% and 30% reductions at the talonavicular and subtalar joints, respectively, after simulated lengthening calcaneocuboid arthrodesis (164). Perhaps the difference in subtalar and talonavicular joint motion in these studies could be attributed to the position of the foot at the time of fusion. Sands et al. demonstrated a clear difference in available motion at the subtalar and talonavicular joints, which was secondary to changes in the position of the foot at the time of fusion. A neutral foot position was recommended to maximize motion in the remaining joint of the rearfoot complex after calcaneocuboid arthrodesis (165).

Lengthening arthrodesis of the calcaneocuboid joint may be an effective form of treatment for adult acquired pes valgus deformity. Long-term follow-up studies are needed to evaluate effects on surrounding joints, longevity of correction, and comparison of efficacy to risks of the procedure. A bone graft of reasonable size is needed to correct foot position. The type of graft needed and the increase in bone healing complications may reduce the use of the procedure because of a poor risk-to-benefit ratio. Toolan et al. followed 41 feet in 36 patients for a mean of 34 months after distraction arthrodesis of the calcaneocuboid joint as a primary procedure for peritalar subluxation of the foot secondary to tibialis posterior dysfunction. Despite a significant complication rate (20% nonunion rate and 71% required additional procedures), Toolan et al. reported that 35 of the 41 feet were rated as satisfactory, and 33 of the 36 patients stated they would have the procedure again (161).

Indications

The primary indications for isolated arthrodesis of the calcaneocuboid joint are limited. Intraarticular joint disease, particularly arthritis, is rare. Some calcaneal fractures may actually spare significant subtalar joint disease and may have a more profound effect on the calcaneocuboid joint. Anterior beak fractures and extensor digitorum brevis avulsion fractures are two primary sources of arthritis of this joint. Isolated cuboid fractures and midtarsal joint compression injuries such as the "nutcracker injury" may also result in significant arthritis at this level.

More recently, physicians performing plantar fascial releases for chronic heel pain syndromes have noted a vague "lateral column syndrome." This has been particularly true of the newer endoscopic plantar fascia release. Although extensive "tincture of time" may resolve the problem along with aggressive physical therapy and custom-made orthotic devices, some patients have ultimately required stabilization arthrodesis of the joint to reduce symptoms. Whereas this joint can be readily and easily fused in patients with this condition, complete elimination of symptoms is unlikely.

Isolated arthrodesis of the calcaneocuboid joint is also indicated in patients with either cavovarus deformity or its mirror image deformity, pes valgo planus. A prerequisite is the absence of intraarticular joint disease of the subtalar or talonavicular joint. In adult acquired pes valgus deformity, the joint is fused by a distraction technique employing a corticocancellous bone graft. In some patients with nonprogressive cavovarus deformity, isolated arthrodesis of the calcaneocuboid joint may correct for the transverse plane component. This usually involves some type of medial release,

tendon transfer, or calcaneal osteotomy for correction of the frontal plane varus deformity.

Although calcaneocuboid arthrodesis with bone block distraction technique is most effective for patients with transverse planar deformities, it does not imply that isolated talonavicular or subtalar joint fusion cannot accomplish the same transverse plane repositioning. All three isolated rearfoot fusions can indeed correct for multiplanar deformity including the transverse plane abduction. However, it appears that lateral column fusion may pose fewer restrictions on the motion of adjacent joints. Whether a patient functions better or has a better quality of life because of this preserved motion is conjecture.

Fusion of this joint necessitates procurement of an autogenous bone graft, which increases surgical morbidity. Furthermore, although it is only one joint by definition, in reality two interfacing sites require healing: the distal cuboid-graft interface and the proximal calcaneus-graft interface site.

Surgical Technique

An incision is made over the dorsal lateral aspect of the calcaneal cuboid joint from the sinus tarsi area to the base of the fourth and fifth metatarsal cuboid articulations. Once again, the incision should be placed superior the sural nerve and the peroneal tendons. Dissection is deepened through the subcutaneous tissues by sharp and blunt techniques to the layer of deep fascia, which is easily demarcated by the retinaculum overlying the distal portion of the extensor digitorum brevis muscle belly superiorly and the peroneal tendons inferiorly. A communicating nerve between the sural and the intermediate dorsal cutaneous nerves may be visualized from the proximal aspect of the incision during subcutaneous tissue dissection. Separation of the subcutaneous tissue and deep fascia is then performed with blunt dissection throughout the entire length of the incision.

A linear deep fascial incision is then placed superior to the peroneal tendons and parallel to the peroneal tendons throughout its entire length. The extensor digitorum brevis muscle belly and capsular ligamentous structures are then dissected dorsally. If significant tension results from excessive inclination of the neck of the calcaneus, then a standard vertical incision into the sinus tarsi can be performed to lift up the entire extensor digitorum brevis muscle belly and deep fascial structures in one layer without significant tension. If this maneuver is performed, the ligamentous structures of the sinus tarsi are left intact. Laterally and inferiorly, the deep fascial structures are dissected free. The entire dorsal surface of the cuboid should be visualized, as well as the lateral aspect where the peroneus longus will be seen passing through the cuboid groove.

The calcaneal cuboid joint is a transverse joint. Joint resection may be accomplished with hand or power instrumentation. If hand instruments are employed, then a miniature distractor or baby laminar spreader may work well to provide enhanced access to the area (Fig. 51). If one uses a miniature distractor of some type, it is advised to place Steinmann pins from the dorsal to plantar direction. This technique facilitates distraction and graft placement. Placing the miniature distractor from dorsal to plantar also allows for easy placement of staple fixation or plate fixation, depending on which type of calcaneal cuboid joint arthrodesis is being performed. If staple fixation is desired and no graft is used, it is easy to distract the joint, to perform cartilage resection, and subsequently to compress the joint in the desired position of fusion before fixation.

FIG. 51. Distraction of the calcaneal cuboid joint employing a baby laminar spreader.

If a bone graft is used for distraction-type arthrodesis, we recommend that autogenous iliac crest bone be used because of its good osteoinductive and osteoconductive properties. The composite corticocancellous nature of the graft is stable. At least 1 cm in width of bone should be harvested from the iliac crest.

Although the posterior superior aspect of the calcaneus is an excellent donor site for autogenous bone harvesting, this technique does not provide enough bone from dorsal to plantar to achieve good osseous graft contact from dorsal to plantar on both sides of the graft calcaneal cuboid interface. If one elects to use an allogeneic bone graft, specimens from the patella or calcaneus provide excellent height from dorsal to plantar surfaces at the fusion site while giving the same cancellous cortical composite for bone healing and stability, respectively.

If there is difficulty with bone apposition with either the calcaneus or the cuboid graft interface, one can perform reciprocal planing on either or both sides of the graft; however, the surgeon must appreciate that further shortening will occur. Alternatively, one may remove the graft and remodel either the calcaneal or the cuboid surface for appropriate fit. It is not uncommon to have to remove the entire portion of

the medial cuboid joint surface as a result of the normal flare and contour of this portion of the joint. We often do this after cartilage resection. This technique facilitates apposition of the graft or fusion site and is easily back grafted after application of fixation if too much of this area is resected with an osteotome or sagittal saw.

Fixation

Although *fixation* of the calcaneocuboid joint arthrodesis appears to be straightforward, this part of the procedure can have pitfalls and difficulties.

If screw fixation is attempted, the screw may be directed from a distal to proximal fashion. This approach requires deep fascial dissection and exposure of the fourth and fifth metatarsal cuboid articulation. When inserting a screw in this fashion, the surgeon must perform adequate countersinking at the distal aspect of the cuboid to achieve good purchase of the screw without creating stress risers at the distal cuboid or an irritating prominence of the screw head.

If the slope of the neck of the calcaneus is inclined (a large calcaneal beak), it may be preferable to place the screw from a proximal to distal fashion. A single large screw or multiple smaller diameter screws can be used for fixation in the joint in this fashion. Typically, we use one or two 4.0- to 5.0-mm cancellous screws. Kann et al. evaluated screw placement for a calcaneocuboid fusion site. They concluded that an axially placed screw from proximal to distal provided superior stiffness and maximum load to failure compared with an oblique screw placed from proximal to distal (166).

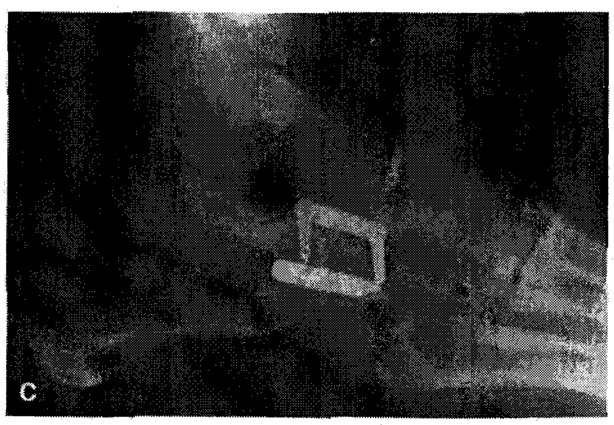


FIG. 52. A: Intraoperative photograph of the calcaneal cuboid joint arthrodesis fixed with two large barbed staples. It is preferable to insert the staples at a 90-degree angle to each other, if possible, to maximize stability. **B,C:** Postoperative dorsoplantar and lateral radiographs of an isolated calcaneal cuboid joint arthrodesis using barbed staples.

More commonly, we use large barbed staples for fixation of this joint (Fig. 52). The minidistractor may be used to generate compression before placement of staples. Once again, the pins for the minidistractor need to be placed in a dorsal to plantar direction to facilitate insertion of the staples. This allows for excellent stability and flesh fit of the staples at the arthrodesis site. It is advised to attempt to place the staples in 90-degree relation to each other whenever possible. This is easily accomplished by placing the staple that goes from lateral to medial first, removing the distractor, and then placing the sagittal plane staple from dorsal to plantar last. After proper joint resection, positioning, and subsequent compression and fixation, the arthrodesis site is inspected.

Plate fixation represents yet another technique for fixation of the calcaneocuboid joint, but it is usually reserved for those cases involving a significant bone graft to lengthen the lateral column or to repair a nonunion of a previous fusion. Plates allow for insertion of screws into the graft directly and several screws to be inserted into the calcaneus and cuboid to provide excellent rigidity to the area. Eccentric drilling techniques also enhance compression at the graft-host interfaces.

POSTOPERATIVE MANAGEMENT

Successful isolated rearfoot fusion includes significant postoperative *convalescence*. Initially, the patient is managed in a Jones compression dressing or posterior splint with or without a surgical drain. The initial dressing is usually changed at 5 to 7 days postoperatively. Ultimately, the patient is managed in a short leg cast after stabilization of the postoperative edema. The patient is maintained non–weight bearing in a short leg cast for 9 to 12 weeks, until clinical and radiographic confirmation of osseous consolidation has been achieved. In some patients, the cast may be bivalved once the wounds have healed, to initiate ankle joint range of motion. Orthotic devices may be employed as necessary to accommodate residual deformity in the rearfoot or forefoot areas.

COMPLICATIONS

As with most surgical procedures, complications can and do occur after major rearfoot fusions. *Wound complications* such as dehiscence, hematoma, seroma, partial-thickness or full-thickness slough may develop. Local wound care measures are usually successful in resolving these problems. Meticulous surgical techniques employing the principles of anatomic dissection and careful wound closure minimize the frequency of these complications. Generally, these measures result in a smaller degree of postoperative edema, which may be a primary factor in the development of many wound problems.

Postoperative infection is potentially a major disaster that may produce more protracted sequelae including osteomyelitis of the tarsal bones. Incision and drainage with débridement are recommended along with appropriate antibiotic therapy. In many patients, delayed primary closure can be performed within the first 5 to 7 days to minimize both the physical scarring and emotional distress associated with postoperative infections.

Entrapment neuropathies can also occur on the medial or lateral aspect of the foot because of the proximity of the incisions relative to the nerve branches. The terminal branch of the sural nerve, the lateral dorsal cutaneous nerve, is readily identifiable and should be retracted inferiorly. Not uncommonly, a communicating branch of this nerve crosses directly through the surgical area and may require excision at the time of surgery. The saphenous nerve accompanies the greater saphenous vein medially and should be retracted dorsally in most cases. Because of the number of branches innervating the medial aspect of the foot and ankle, some postoperative numbness may develop, but in most cases it resolves over time.

Problems may also be seen with *delayed union, nonunion, and malunion* (Fig. 53). Although many of these complications can be prevented by following sound surgical techniques and principles, some of are unfortunately inevitable. Some cases of disturbed bone healing are obvious, whereas others are difficult to appreciate. Persistent complaints of pain and swelling directly at the fusion site suggest compromised healing. Serial radiographs are often helpful to identify and confirm the problem. Subtle changes in position of the joint and bones, migration of or radiolucency around the internal fixation devices, bone callus formation, and sclerosis or frank radiolucency all suggest a delayed union. Persistence of these findings may herald a definitive nonunion or pseudarthrosis. Once delayed union is suspected, non–weight bearing and immobilization should be reinstituted. A noninvasive electrical bone stimulator may be a helpful adjunct to healing. To the extent possible, patients may need to reduce or terminate other external factors that may adversely affect healing, such as nicotine consumption.

When frank nonunion occurs, surgical intervention is likely to be required. In most cases, an autogenous corticocancellous bone graft is needed. The most common donor site is the anterior or posterior iliac crest; the calcaneus or distal tibia may be sufficient in some cases. The use of allogeneic bone alone is generally not employed. Some demineralized bone graft products may be helpful because of their properties of osteoinduction. In other instances, allogenic bone may be employed with the autogenous material to reduce the need for harvesting additional material from the donor site. Finally, the internal fixation itself is usually replaced or enhanced.

The use of internal fixation plates may also be beneficial in some cases, especially for the talonavicular and calcaneocuboid joints. Although these devices are less effective at imparting compression at the site, they can provide excellent rigidity to the area and permit insertion of multiple screws

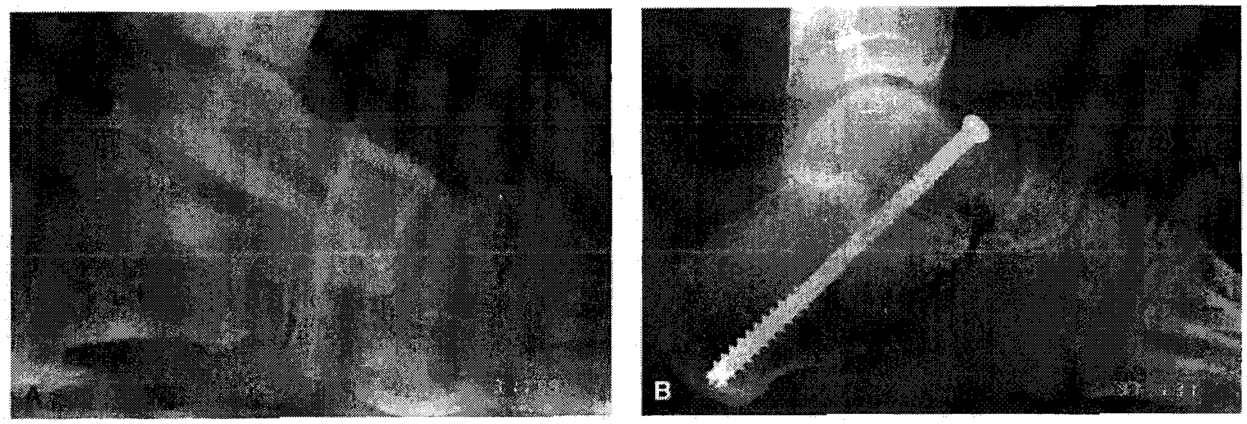


FIG. 53. A: Nonunion of a talonavicular arthrodesis fixed with staples. Note the presence of a radiolucent line as well as bone callus formation dorsally. **B:** Nonunion of a subtalar joint arthrodesis. Note the sclerosis of the fusion site and a faint but visible radiolucent line. Significant clinical symptoms were present. Revision arthrodesis was required.

in a direction that does not compete with previous drill hole sites. Small external fixation devices may also be considered.

Malunion or malposition after rearfoot arthrodesis may also be seen. The surgical techniques employed to repair undercorrection or overcorrection vary depending on the severity of the deformity, the quality of the original fusion, and the personal experience and philosophy of the surgeon. These problems are always challenging, even for the most experienced surgeons. Undercorrection is generally better tolerated than overcorrection. In most cases, a trial of custom-made orthotic devices or some type of bracing alone or in combination with shoe modifications may help. If this approach is ineffective, surgical revision of the fusion is likely to be necessary. This may necessitate a revision of the original fusion with or without bone grafting, fusion of additional joints, or an extraarticular osteotomy.

If the subtalar joint has been fused in a varus attitude, it may be possible to correct the problem by way of a Dwyer calcaneal-type osteotomy with or without fusion of the calcaneocuboid joint to correct for adduction of the midfoot (Fig. 54). Overcorrection with fusion of the talonavicular joint requires a similar approach or conversion to a triple arthrodesis. In the case of overcorrection after a calcaneocuboid arthrodesis, it will likely be necessary to revise the original fusion; undercorrection can be corrected by fusion of the subtalar joint in a neutral attitude, which corrects for both frontal plane valgus and transverse plane abduction.

Forefoot varus or supinatus deformity previously uncorrected or unrecognized can be a difficult problem. If it is not responsive to shoe modification or accommodative orthotic devices, surgical intervention will become necessary. In some cases, appropriate wedge resection and fusion can correct the medial column malposition (Fig. 55). In other cases, it becomes necessary to revise the original fusion in the direction of pronation. The more supinated the rearfoot complex, the more likely the forefoot varus deformity will be; likewise, the more pronated the rearfoot fusion, the less likely the forefoot varus is to be symptomatic or problematic. If medial column instability is the cause of the symptoms, tenosuspension procedures may prove effective; these include a modified Young tenosuspension or peroneus brevis to longus anastomosis.

FIG. 54. Varus fusion of the subtalar joint from failure to appreciate underlying significant varus deformity of the leg segment preoperatively. A revision arthrodesis was required.

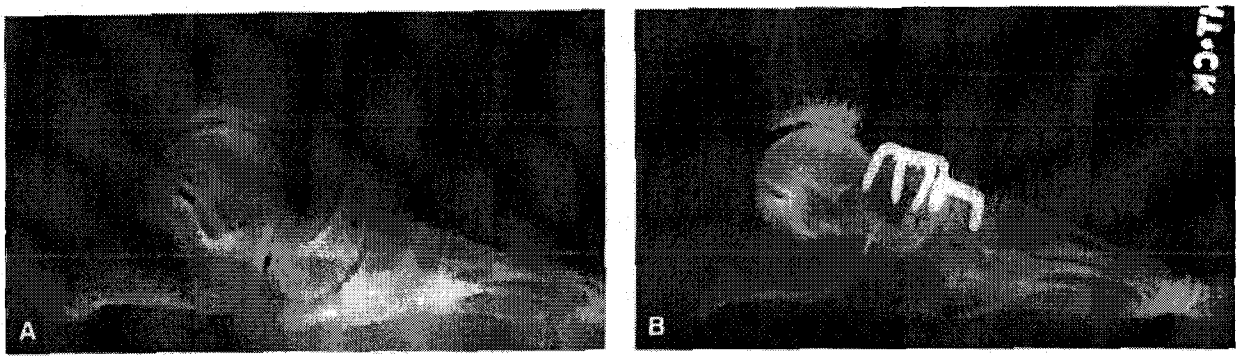


FIG. 55. Preoperative **(A)** and postoperative **(B)** lateral radiographs demonstrating significant medial column faulting corrected by double medial column fusion.

Internal fixation devices employed in rearfoot fusions generally do not loosen or migrate as frequently as they do in the forefoot. When large cancellous screws or staples migrate and loosen, they usually signify a complication of the arthrodesis itself. If solid fusion is confirmed clinically and radiographically, then removal of the device alone is likely to resolve the problem. Reinsertion of another device is not necessary.

Degenerative arthritis of adjacent joints should be thought of more as a sequel of isolated joint arthrodesis rather than as a complication. Adjacent joint arthritis can also occur with double and triple joint fusions. The rapidity with which it occurs appears to be related more to the position of fusion than to the number of joints fused. Fortunately, for most patients, these features are more often incidental findings on radiographs than functional or symptomatic concerns.

SUMMARY AND CONCLUSIONS

Over the years, many refinements have been made in the techniques of major rearfoot fusions. These include enhanced anatomic dissection techniques and various methods of joint resection and fixation. The combination of meticulous surgical technique and proper joint positioning has produced rewarding results for both patients and surgeons alike.

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